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Jaggery Juice in Cancer Therapy: Nutritional Composition, Pharmacological Benefits and Future Perspectives

Iqbal T*

Institute of Physiology and Pharmacology, University of Agriculture, Faisalabad, Pakistan

***Corresponding author:** Iqbal T, Institute of Physiology and Pharmacology, University of Agriculture, Faisalabad, Pakistan

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Abstract

Jaggery juice, a traditional sweetener derived from sugarcane, has recently garnered attention for its potential therapeutic applications, particularly in the context of cancer therapy. Unlike refined sugar, jaggery juice is rich in essential nutrients and bioactive compounds, including polyphenols, flavonoids, and minerals such as iron, calcium, and magnesium. These constituents contribute to its diverse pharmacological profile, encompassing antioxidant, anti-inflammatory, immunomodulatory, and detoxifying properties and mechanisms that are critical in the prevention and management of cancer. Emerging in vitro and in vivo studies suggest that jaggery juice may inhibit carcinogenesis through the scavenging of reactive oxygen species, suppression of pro-inflammatory pathways, and enhancement of immune surveillance. These biological effects are particularly relevant given the role of oxidative stress and chronic inflammation in tumor progression. Furthermore, jaggery juice has shown promise in enhancing the efficacy of chemotherapeutic agents and mitigating their side effects, indicating its potential role as an adjunctive treatment. Despite these promising findings, clinical evidence remains limited, and challenges such as lack of standardization, variability in composition, and insufficient clinical trials must be addressed. Future research should focus on elucidating molecular mechanisms, conducting controlled clinical studies, and developing standardized jaggery-based nutraceuticals. Overall, jaggery juice holds significant promise as a functional food in cancer therapy. Its integration into dietary strategies may offer a natural, accessible, and cost-effective approach to complement conventional cancer treatments. Continued research and validation are necessary to fully harness its therapeutic potential in oncology.

Key words: Jaggery juice; Cancer therapy, Antioxidants; Anti-inflammatory; Phytochemicals; Functional foods

Introduction

Background on cancer as a global health concern

Cancer remains one of the leading causes of morbidity and mortality worldwide, posing a major public health challenge across both developed and developing nations [1]. According to the World Health Organization (WHO), cancer accounted for nearly 10 million deaths in 2020, with lung, colorectal, liver, stomach, and breast cancers being the most prevalent. The growing burden is attributed to aging populations, unhealthy lifestyles, environmental pollution, and limited access to early detection and treatment in many regions [2]. Despite advances in chemotherapy, radiotherapy, and targeted therapies, cancer treatment is often associated with significant side effects, toxicity, drug resistance, and high financial costs. These limitations underscore the urgent need to explore alternative or complementary therapies that are not only effective but also safe, affordable, and accessible. Over the past few decades, there has been increasing global interest in natural products and traditional medicinal systems as sources of novel anticancer agents [3]. Among these, dietary interventions and functional foods rich in bioactive compounds have gained attention for their potential chemo preventive and therapeutic effects. Jaggery juice, a traditional, unrefined sweetener derived from sugarcane, is one such food source known for its high nutritional and phytochemical content [4]. Recent evidence suggests that jaggery juice contains several bioactive components such as polyphenols, flavonoids, saponins, and micronutrients which may exhibit antioxidant, anti-inflammatory, and anticancer properties.

This review aims to explore the nutritional composition, pharmacological benefits, and future research potential of jaggery juice in the context of cancer therapy [5].

Introduction to jaggery juice: traditional uses and emerging scientific interest

Jaggery juice, a natural, unrefined product obtained from sugarcane (Saccharum officinarum), has been a staple in traditional diets across South Asia, Africa, and parts of Latin America for centuries. Commonly consumed in its liquid or concentrated solid form, jaggery is highly valued in Ayurvedic and folk medicine for its warming, detoxifying, and digestive properties [6]. Traditionally, it has been used to treat respiratory conditions, improve digestion, relieve joint pain, and enhance general vitality, particularly in colder seasons. Unlike refined sugar, jaggery retains essential minerals and phytochemicals due to its minimal processing [7]. In recent years, jaggery juice has attracted scientific interest owing to its rich nutritional profile and potential therapeutic properties. Studies have identified it as a source of key micronutrients such as iron, calcium, magnesium, potassium, and phosphorus, as well as bioactive compounds like polyphenols, flavonoids, saponins, and antioxidants. These constituents are known to exert anti-inflammatory, immunomodulatory, and free radical-scavenging effects, making jaggery juice an applicant for disease prevention and health promotion [8]. The growing recognition of the link between diet and chronic diseases, including cancer, has prompted researchers to explore jaggery juice not only as a nutritional supplement but also as a functional food with possible chemo preventive benefits. This emerging perspective bridges traditional knowledge with modern pharmacological inquiry, providing a promising foundation for further studies into its role in integrative cancer therapy [9].

Rationale for exploring jaggery juice in cancer therapy

The global burden of cancer, coupled with the adverse effects and limitations of conventional treatments such as chemotherapy and radiotherapy, has intensified the search for complementary and alternative therapeutic approaches [10]. Natural products, particularly those derived from dietary sources, have emerged as promising candidates due to their safety profile, accessibility, and presence of bioactive phytochemicals. Jaggery juice, a traditional, minimally processed product derived from sugarcane, offers a unique combination of nutritional and pharmacological benefits that merit scientific investigation in the context of cancer therapy [11]. Jaggery juice contains a variety of health-promoting compounds including polyphenols, flavonoids, saponins, tannins, vitamins (e.g., B-complex, C), and essential minerals (iron, magnesium, calcium, potassium). These compounds are known to exert antioxidant, anti-inflammatory, immunomodulatory, and detoxifying effects mechanisms that are central to cancer prevention and treatment [12]. Oxidative stress and chronic inflammation are well-established contributors to cancer initiation, progression, and metastasis. The ability of jaggery juice constituents to scavenge reactive oxygen species (ROS), inhibit pro-inflammatory cytokines, and support immune function presents a plausible pathway for its therapeutic relevance [13]. Moreover, preliminary in vitro and in vivo studies suggest that certain phytochemicals present in jaggery may induce apoptosis, inhibit angiogenesis, and enhance the efficacy of conventional drugs while reducing their toxicity. Given its historical use in traditional medicine and emerging scientific evidence, jaggery juice represents a cost-effective and culturally acceptable candidate for further exploration in integrative cancer therapy [14].

Scope and objectives of the review

This review aims to provide a comprehensive and evidence-based exploration of jaggery juice as a potential adjunct in cancer therapy. While jaggery has long been used in traditional medicine for its general health benefits, scientific evaluation of its pharmacological potential, especially in oncology, remains limited. This article bridges the gap between traditional knowledge and emerging biomedical research by examining the nutritional and bioactive components of jaggery juice in the context of cancer prevention and treatment [15].

Figure 1: *Overview of Jaggery Juice.*

The review covers the nutritional composition of jaggery juice, emphasizing its vitamins, minerals, and essential micronutrients. It also discusses pharmacologically active compounds such as polyphenols, flavonoids, saponins, and tannins, focusing on their biological mechanisms related to cancer. The potential therapeutic roles of these constituents in preventing carcinogenesis, inhibiting tumor growth, and enhancing immune function are critically assessed [16]. Additionally, existing experimental studies, both in vitro and in vivo, supporting its anticancer efficacy are reviewed. Finally, future research directions and practical considerations for integrating jaggery juice into complementary cancer care are highlighted. By consolidating current knowledge and identifying key gaps, this review encourages further scientific inquiry and underscores the need for rigorous clinical validation to confirm its safety and therapeutic potential [17] (Figure 1).

Nutritional Composition of Jaggery Juice

Macro- and micronutrients

Jaggery juice, a traditional sweetener derived from sugarcane, is a rich source of both macro- and micronutrients that contribute to its health-promoting potential. Unlike refined sugar, jaggery retains essential nutrients due to its minimal processing, making it a functional dietary component with nutritional and therapeutic value [18]. Carbohydrates are the primary macronutrient in jaggery juice, primarily in the form of sucrose, glucose, and fructose. These natural sugars provide an immediate energy source, making jaggery juice a traditional remedy for fatigue and weakness. Although protein and fat contents are minimal, they are present in trace amounts, mainly from plant-based residues retained during extraction [19]. Jaggery juice is particularly notable for its vitamin content, including water-soluble B-complex vitamins such as thiamine (B1), riboflavin (B2), niacin (B3), and pyridoxine (B6), which are essential for cellular metabolism and nervous system function. Vitamin C (ascorbic acid) is also present and acts as a potent antioxidant that supports immune function and collagen synthesis, both critical in cancer prevention and tissue repair [20,21]. Among the micronutrients, jaggery juice is especially rich in iron, which helps combat anemia a common comorbidity in cancer patients. Calcium and magnesium play key roles in bone health, neuromuscular function, and enzymatic activity, while potassium aids in fluid balance and cellular function. Phosphorus, zinc, and trace elements like copper and selenium further enhance its nutritional profile, contributing to antioxidant defense and immune regulation. The synergistic presence of these nutrients not only supports overall health but also suggests a role in modulating oxidative stress and immune function—two critical factors in cancer development and progression. Hence, the nutritional composition of jaggery juice lays a foundational basis for its therapeutic exploration in oncology [22].

Phytochemicals and bioactive compounds

Jaggery juice is not only valued for its nutritional components but also for its rich content of phytochemicals and bioactive compounds that offer potential therapeutic benefits, particularly in the context of chronic diseases such as cancer. These naturally occurring substances play crucial roles in antioxidant defense, immune modulation, and cellular protection.

One of the major classes of phytochemicals present in jaggery juice is polyphenols. These compounds are known for their potent antioxidant activity, which helps scavenge free radicals and reduce oxidative stress—a key factor in the initiation and progression of cancer. Polyphenols may also modulate signaling pathways involved in inflammation, apoptosis, and cell cycle regulation, providing a multi-targeted approach to cancer prevention [23]. Flavonoids, a subgroup of polyphenols, are also abundant in jaggery juice. These include quercetin, kaempferol, and luteolin, which are recognized for their anti-inflammatory, anti-proliferative, and anti-angiogenic properties. Studies have demonstrated that flavonoids can inhibit tumor growth by inducing cell cycle arrest and apoptosis in various cancer cell lines, supporting their role as natural chemo preventive agents [24]. In addition, jaggery juice contains saponins and alkaloids, which contribute to its therapeutic potential. Saponins are known to possess immunomodulatory, cytotoxic, and anti-metastatic activities, while certain alkaloids can interfere with tumor cell signaling and enhance the efficacy of conventional drugs.

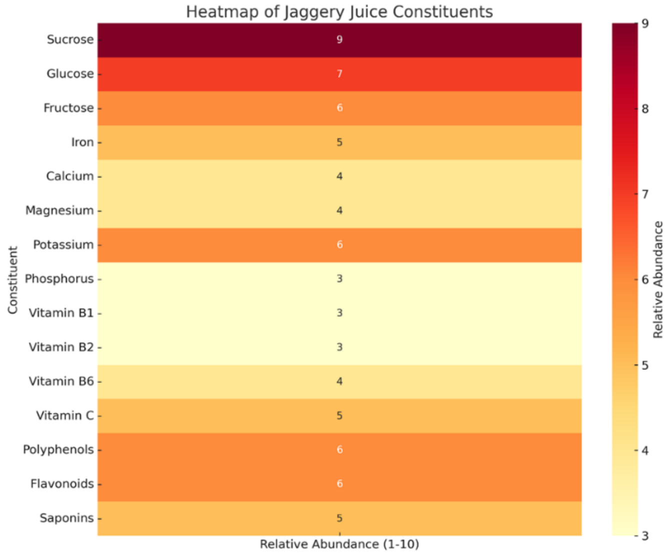

Figure 2: *The Heatmap of Jaggery Juice Constituents.*

Lastly, the antioxidant profile of jaggery juice is enhanced by the presence of compounds such as tannins and ascorbic acid, which collectively reduce oxidative damage and inflammation. These antioxidant properties are crucial in cancer therapy, as they protect normal cells from treatment-induced damage while selectively targeting malignant cells [25]. Thus, the diverse array of bioactive constituents in jaggery juice provides a promising foundation for its development as a functional food with anticancer properties [26] (Figure 2).

Comparison with refined sugar and natural sweeteners

Jaggery juice stands out among sweeteners for its superior nutritional and phytochemical profile, particularly when compared to refined sugar and other commonly used natural alternatives such as honey, agave nectar, and maple syrup. Unlike refined sugar, which undergoes extensive processing and is devoid of essential nutrients, jaggery juice retains a significant portion of sugarcane's original vitamins, minerals, and bioactive compounds [27]. Refined sugar (sucrose) consists purely of empty calories, contributing to metabolic disorders such as obesity, type 2 diabetes, and cardiovascular disease without providing any nutritional benefit. In contrast, jaggery juice contains complex carbohydrates, iron, calcium, potassium, magnesium, and a range of antioxidants, making it a more balanced energy source with added health benefits [28]. Compared to other natural sweeteners, jaggery juice shares similarities with honey regarding antioxidant activity and trace mineral content. However, jaggery may offer higher levels of certain minerals such as iron and magnesium. Unlike agave nectar, which has a high fructose content associated with insulin resistance, jaggery juice has a lower glycemic impact and additional detoxifying effects recognized in traditional medicine. Replacing refined sugar with jaggery juice may offer several health advantages, including improved antioxidant intake, enhanced immune function, and reduced oxidative stress. These benefits are especially relevant for cancer patients, who often experience oxidative damage, inflammation, and nutritional deficiencies due to the disease and its treatments. Moreover, jaggery's bioactive compounds may contribute to a protective effect against cancer by modulating inflammatory pathways and supporting cellular detoxification. While moderation remains essential due to its sugar content, the therapeutic value of jaggery juice as a functional sweetener makes it a promising alternative for health-conscious individuals and those undergoing cancer therapy [29].

Mechanism of action by which jaggery juice affects cancer

Jaggery juice contains a variety of bioactive compounds such as polyphenols, flavonoids, saponins, and antioxidants, which contribute to its potential anticancer effects through several mechanisms. Its antioxidant properties play a crucial role in neutralizing free radicals and reducing oxidative stress, which is known to cause DNA damage and mutations that can initiate cancer [30]. By minimizing oxidative damage, jaggery juice helps protect cellular integrity and prevent carcinogenesis. Additionally, jaggery juice exhibits anti-inflammatory effects by inhibiting pro-inflammatory cytokines like TNF-α and IL-6, as well as downregulating signaling pathways such as NF-κB and COX-2, which are involved in creating an environment conducive to tumor growth and metastasis. It also modulates the immune system by activating macrophages and T-cells, enhancing the body's ability to identify and eliminate cancer cells [31]. Furthermore, the phytochemicals in jaggery juice can induce apoptosis and cause cell cycle arrest in cancer cells, preventing their uncontrolled proliferation. Jaggery juice also supports liver function and facilitates the detoxification and elimination of carcinogens and heavy metals, reducing exposure to substances that promote cancer development. Collectively, these mechanisms highlight jaggery juice's potential as a multi-targeted agent in cancer therapy, although further research is necessary to confirm its clinical efficacy [32] (Table 1).

Table 1: *Major Chemical Compounds Present in Jaggery Juice and Their Relative Concentration.*

Sr.No.	Component/Study	Property/Effect	Source	Target Cancer Type	Remarks	References
1	Polyphenols	Antioxidant activity	Jaggery juice	General	Scavenges free radicals	(Pujari et al., 2025)
2	Flavonoids	Anti-inflammatory	Jaggery juice	Colorectal	Inhibits COX-2	(Nisar et al., 2023)
3	Iron	Immune function	Jaggery juice	General	Supports hematopoiesis	(Abuaraki et al., 2024)
4	Magnesium	DNA repair	Jaggery juice	Breast	Cofactor for repair enzymes	(Mukherjee et al., 2025)
5	Alkaloids	Cytotoxicity	Jaggery juice	Lung	Induces apoptosis	(Dewangan et al., 2025)
6	Saponins	Antitumor	Jaggery juice	Prostate	Disrupts cancer cell membrane	(Birajdar et al., 2025)

7	Vitamin C	DNA protection	Jaggery juice	Skin	Prevents oxidative damage	(Hussain et al., 2021)
8	Animal study (Rat model)	Tumor suppression	In vivo	Colon	Reduced tumor size	(Sugimura et al., 2022)
9	NF-κB pathway inhibition	Anti-inflammatory	Mechanism observed	Pancreatic	Blocks inflammatory signaling	(Piao et al., 2020)
10	T-cell activation	Immunomodulation	Preclinical study	Melanoma	Enhances immune response	(Kalaora et al., 2022), (Altaf & Iqbal, 2023)
11	ROS scavenging	Antioxidant	Jaggery compounds	Liver	Reduces oxidative stress	(Nhung & Quoc, 2024)
12	Flavonoid-rich diet	Synergistic effect	Diet-based approach	Multiple	Potential in combination	(Haro-Reyes et al., 2024)
13	Traditional medicine use	General wellness	Ethnobotanical data	-	Widely consumed in Asia	(PANYADEE et al., 2024),(T. Iqbal, Altaf, Basit, et al., 2024)
14	Detoxification enzymes	Carcinogen elimination	Liver enzyme boost	General	Enhances phase II enzymes	(Potęga, 2022)
15	Human observational study	Reduced cancer risk	Epidemiological data	General	Needs clinical confirmation	(Solmi et al., 2023)

Pharmacological Benefits Relevant to Cancer Therapy

Antioxidant Activity: Jaggery juice exhibits significant free radical scavenging ability due to its high content of polyphenols, flavonoids, and vitamin C. These antioxidants neutralize reactive oxygen species (ROS) and reduce oxidative stress, which is implicated in DNA damage and carcinogenesis. By preventing oxidative stress-induced cellular damage, jaggery juice may help maintain genomic stability and protect normal cells from transformation [33].

Anti-inflammatory Properties: Chronic inflammation is a recognized driver of cancer progression. Jaggery juice has demonstrated the capacity to inhibit key pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and interleukin-1β (IL-1β). Its bioactive compounds modulate important signaling pathways including nuclear factor kappa B (NF-κB) and cyclooxygenase-2 (COX-2), both of which regulate inflammation and cellular proliferation. Through these mechanisms, jaggery juice may reduce the inflammatory microenvironment conducive to tumor growth [34].

Immunomodulatory Effects: Immune surveillance plays a critical role in identifying and eliminating cancer cells. Jaggery juice stimulates the activation of immune effector cells such as macrophages and T-lymphocytes, enhancing the body's natural defense mechanisms. These immunomodulatory effects support improved recognition and destruction of malignant cells, potentially improving cancer prognosis [35,36].

Anticancer Potential (In Vitro & In Vivo Evidence): Preclinical studies provide promising evidence that jaggery juice and its phytochemicals can induce apoptosis in various cancer cell lines, promoting programmed cell death and preventing uncontrolled proliferation. Additionally, jaggery components have been shown to cause cell cycle arrest at critical checkpoints, inhibiting cancer cell division and metastasis. Some studies suggest synergistic effects when combined with conventional chemotherapeutic agents, potentially enhancing efficacy and reducing drug resistance, although more research is required [37].

Detoxifying Effects: Jaggery juice supports liver function, aiding in the metabolism and clearance of toxins. Its rich mineral content facilitates chelation and elimination of carcinogens and heavy metals, which are risk factors for cancer development. By promoting detoxification, jaggery juice may reduce the overall toxic burden, thereby complementing cancer prevention and therapy [38] (Figure 3).

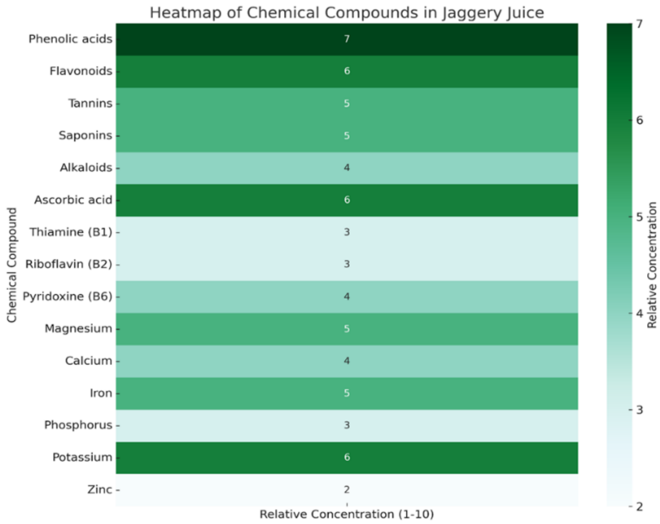

Figure 3: *The Heatmap of Chemical Compounds in Jaggery Juice.*

Table 2: *Major Constituents of Jaggery Juice and Their Health Relevance.*

Sr.No.	Constituent	Type	Function	Health Benefit	Relevance to Cancer Therapy	References
1	Sucrose	Carbohydrate	Energy source	Quick energy	Supports metabolism in cachexia	(Masi & Patel, 2021)
2	Glucose	Simple sugar	Energy supply	Improves stamina	Supports energy levels in patients	(Abuzaid & Hadi, 2024)
3	Fructose	Simple sugar	Enhances palatability	Natural sweetener	Reduces need for refined sugar	(Arshad et al., 2022)
4	Iron	Mineral	Hemoglobin synthesis	Prevents anemia	Supports immune function	(Mitterstiller et al., 2022)
5	Calcium	Mineral	Bone and cell signaling	Strengthens bones	Mitigates cancer-related bone loss	(Othman et al., 2021)
6	Magnesium	Mineral	Enzyme cofactor	Regulates nerve and muscle function	Aids in DNA repair and immune modulation	(Souza et al., 2023)
7	Potassium	Electrolyte	Fluid balance, nerve function	Reduces cramps and fatigue	Maintains cellular integrity	(Yadav et al., 2024)

8	Phosphorus	Mineral	Bone health, energy metabolism	Maintains bone structure	Supports recovery	(Serna & Bergwitz, 2020)
9	Vitamin B1 (Thiamine)	Vitamin	Energy metabolism	Supports nervous system	Boosts energy and immune response	(Mrowicka et al., 2023)
10	Vitamin B2 (Riboflavin)	Vitamin	Antioxidant role	Enhances metabolism	Protects cells from oxidative damage	(Zhang et al., 2022)
11	Vitamin B6 (Pyridoxine)	Vitamin	Protein metabolism	Enhances immune function	Supports lymphocyte activity	(Bargiela et al., 2022)
12	Vitamin C	Vitamin	Antioxidant, collagen synthesis	Enhances immunity	Reduces oxidative stress	(Khadim & Al-Fartusie, 2021)
13	Polyphenols	Phytochemical	Antioxidant, anti-inflammatory	Fights chronic diseases	Inhibits tumor initiation and promotion	(Y.-C. Chen et al., 2021)
14	Flavonoids	Phytochemical	Free radical scavenging	Anti-aging, disease prevention	Suppresses cancer cell proliferation	(Niu et al., 2022)
15	Saponins	Phytochemical	Immunomodulatory, cytotoxic	Enhances immune defense	Induces apoptosis in cancer cells	(Paudel et al., 2023)

Clinical and Preclinical Studies

Experimental studies

Preclinical research investigating the anticancer potential of jaggery juice has primarily utilized animal models and in vitro cell culture systems. Studies in rodents have demonstrated that jaggery supplementation can reduce tumor incidence, inhibit tumor growth, and ameliorate chemotherapy-induced side effects through its antioxidant and immunomodulatory properties. For example, rodent models of chemically induced carcinogenesis showed decreased oxidative stress markers and improved immune response following jaggery administration. These findings underscore jaggery juice's potential in cancer prevention and adjunct therapy. Comparative studies involving jaggery juice alongside conventional chemotherapeutic agents have indicated possible synergistic effects. In certain models, jaggery enhanced the efficacy of chemotherapy drugs by increasing apoptosis in tumor cells while mitigating toxicity in normal tissues. However, these studies remain preliminary, with limited data on optimal dosing and long-term safety [39].

Human observational or interventional studies

Human research on jaggery juice in the context of cancer is currently sparse. Observational studies have reported lower cancer incidence in populations with higher dietary intake of natural sweeteners, including jaggery, compared to those relying heavily on refined sugars, suggesting a potential protective effect. However, confounding factors and limited sample sizes warrant caution in interpretation. Preliminary clinical trial data are limited but emerging, with some small-scale interventions exploring jaggery supplementation's impact on biomarkers of oxidative stress and immune function in cancer patients. These early findings suggest improved antioxidant status and enhanced quality of life, though rigorous randomized controlled trials are needed to establish efficacy, safety, and therapeutic protocols [40].

Challenges and Limitations

Despite the promising therapeutic potential of jaggery juice in cancer therapy, several challenges and limitations hinder its clinical translation and widespread acceptance [41].

One major issue is the lack of standardized formulation and dosing guidelines. Variations in jaggery juice preparation from the source of sugarcane to extraction and storage methods result in inconsistent concentrations of bioactive compounds. This variability complicates the determination of effective and safe doses for therapeutic use, limiting reproducibility in research and clinical settings [42]. Another significant limitation is the scarcity of well-designed clinical trials. Most current evidence is derived from in vitro or animal studies, with very few human studies available. Without robust clinical data, it is difficult to conclusively establish jaggery juice's efficacy, optimal dosing, and safety profile in cancer patients, especially those undergoing conventional treatments [43]. The quality and composition of jaggery juice can vary widely due to differences in processing techniques, geographical factors, and agricultural practices. These factors may affect its nutritional and phytochemical content, potentially alter its therapeutic effects and raise concerns about product consistency. Furthermore, potential risks or contraindications associated with jaggery juice consumption must be considered. Its high sugar content could exacerbate hyperglycemia in diabetic or metabolic syndrome patients. Allergic reactions, interactions with chemotherapeutic drugs, and effects on patients with specific comorbidities remain poorly studied, necessitating caution. Addressing these challenges through standardized production methods, rigorous clinical trials, and safety evaluations will be critical for validating jaggery juice as a viable adjunct in cancer therapy (Table 2).

Future Perspectives

While jaggery juice shows promise in cancer therapy, significant research gaps remain. Mechanistic studies are needed to elucidate the precise molecular pathways through which its bioactive compounds exert anticancer effects. Additionally, bioavailability and pharmacokinetics data are critical to understanding how these compounds are absorbed, metabolized, and distributed in the human body, which will inform effective dosing regimens [44]. Emerging fields like nanocarrier-based delivery systems offer opportunities to enhance the stability, bioavailability, and targeted delivery of jaggery's phytochemicals. Moreover, investigating combination therapies integrating jaggery juice with existing chemotherapeutic or immunotherapeutic agents could reveal synergistic benefits and reduce side effects [45].

Development of functional foods or nutraceuticals

The rich nutritional and bioactive profile of jaggery juice positions it as an ideal candidate for the development of functional foods or nutraceuticals aimed at cancer prevention and adjunctive treatment. Future work can focus on creating formulations that maximize their anticancer potential, such as enriched extracts or blends with complementary compounds. This also aligns with the growing trend toward personalized nutrition and integrative oncology, where dietary interventions are tailored to individual genetic, metabolic, and clinical profiles to optimize therapy outcomes and quality of life [46].

Policy and regulatory considerations

Comprehensive guidelines for standardization, quality control, and safety assessment must be established to facilitate the clinical adoption of jaggery juice-based therapies. Regulatory frameworks need to define manufacturing practices, ensure product consistency, and set protocols for clinical evaluation. This will foster confidence among healthcare providers and patients, promoting responsible and evidence-based use of jaggery juice in cancer care [47-77].

Conclusion

Jaggery juice, rich in essential nutrients and diverse bioactive compounds, offers notable nutritional and pharmacological benefits relevant to cancer therapy. Its potent antioxidant and anti-inflammatory properties, combined with immunomodulatory and detoxifying effects, position it as a promising natural adjunct in cancer prevention and treatment. Experimental studies demonstrate jaggery juice's ability to induce apoptosis, inhibit tumor growth, and enhance immune responses, suggesting significant therapeutic potential. Compared to refined sugar and some natural sweeteners, jaggery juice provides additional health advantages that may improve patient outcomes during cancer therapy. However, limitations such as variability in composition, lack of standardized dosing, and limited clinical evidence highlight the need for further research. Well-designed clinical trials and mechanistic studies are essential to validate its efficacy and safety, optimize formulations, and establish guidelines for its integration into conventional cancer care. Harnessing jaggery juice's full potential could contribute to more holistic, accessible, and effective cancer treatment strategies.

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